DRINKING WATER ON INTERSTATE CARRIERS.

A STUDY OF CONDITIONS ON STEAM VESSELS ENGAGED IN INTERSTATE COMMERCE IN THE SANITARY DISTRICT OF THE GREAT LAKES.

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The fact that contaminated drinking-water supplies on board lake carriers cause a marked increase in the typhoid rate among sailors was first pointed out by Cobb, in 1909,[1] at which time he outlined the various arrangements for obtaining drinking water on board vessels, and briefly discussed the methods of contamination.

In 1910 Young[2] reported an investigation of typhoid fever among the members of crews of lake vessels. In this study he pointed out that the incidence of typhoid fever was higher among seamen on the Great Lakes than among seamen on inland rivers and the seacoast, concluding also from his statistics that the rate was considerably higher than in lake cities, and that the water supplies of the vessels were in many cases contaminated.

De Valin,[3] in 1914, made an epidemiological study of typhoid-fever epidemics on two lake vessels, and in connection with this discussed the question of water supply and sewage disposal somewhat in detail, outlining in a general way possible methods of solution.

In 1909 Young and Judson[4] suggested that the interstate quarantine regulations might be amended so as to control the disposition of sewage from lake vessels. Active corrective measures were not undertaken at the time, but in 1913 the interstate quarantine regulations were so amended as to put the control of drinking-water supplies aboard interstate common carriers under the supervision of the Public Health Service. Other amendments were subsequently made. At the present time the following regulations relate to the water supplies of interstate common carriers:

REVISED INTERSTATE QUARANTINE REGULATIONS.

SEC. 13. Water provided by common carriers on cars, vessels, or vehicles operated in interstate traffic for the use of passengers shall be furnished under the following conditions:

(*a*) Water shall be certified by the interstate sanitary officers or the State or other health authorities within whose jurisdiction it is obtained as conforming

[1] "Water contamination aboard ship and its prevention," by Surg. J. O. Cobb, U. S. Public Health Service, Journal of the American Medical Association, vol. 53, p. 2057, Dec. 18, 1909.

[2] "Relation of shipping on the Great Lakes to the spread of typhoid," by Surg. G. B. Young, U. S. Public Health Service, Second Report of Lake Michigan Water Commission, p. 97.

[3] "Water supplies of ships," by Hugh de Valin, passed assistant surgeon, U. S. Public Health Service, from Public Health Reports, vol. 29, No. 7, Feb. 13, 1914.

[4] "Control of shipping," by Dr. G. B. Young and Maj. W. V. Judson, First Report of Lake Michigan Water Commission, p. 125.

to the standard of purity of drinking water supplied to the public by common carriers engaged in interstate traffic, as promulgated by the Secretary of the Treasury on October 21, 1914: *Provided,* That water in regard to the safety of which a reasonable doubt exists may be used if the same has been treated in such manner as to render it incapable of conveying disease, and the fact of such treatment is certified by the aforesaid health officer.

(*b*) Ice used for cooling such water shall be clear natural ice, or ice made from distilled water or water certified as aforesaid, and before the ice is placed in the water it shall be first carefully washed with water of known safety and handled in such manner as to prevent its becoming contaminated by the organisms of infectious or contagious diseases: *Provided,* That the foregoing shall not apply to ice which does not come in contact with the water which is to be cooled.

(*c*) Water containers shall be cleansed at least once in each week that they are in operation.

SEC. 14. Common carriers while engaging in interstate traffic shall not furnish to their crews or employees any polluted water for drinking purposes which may contain organisms or materials likely to cause a contagious or infectious disease, nor shall such carriers maintain or permit to be maintained upon their vessels or vehicles, or at or near their stations or other ordinary stopping places over which they have control, any tank, cistern, receptacle, hydrant, or article with water which may contain such impurities, in such manner that water therefrom may be conveniently obtained by the crews and employees mentioned for drinking purposes, unless such common carriers maintain a notice upon said vessels or vehicles and at, near, or upon every said tank, cistern, receptacle, hydrant, pump, well, stream, brook, pool, ditch, or other place or article, with water therein containing such impurities, forbidding the use of such water for drinking purposes by the crews or employees of the said common carriers or by the general public while engaging in interstate commerce.

SEC. 15. No person, firm, or corporation shall furnish water for drinking or cooking purposes to any vessel in any harbor of the United States intending to clear for some port within some other State or Territory of the United States, or the District of Columbia, taken from the waters of such harbor or from any other place where it has been or may have been contaminated by sewer discharges: *Provided,* That water in regard to the safety of which a reasonable doubt exists may be used if the same has been treated in such manner as to render it incapable of conveying disease, and the fact of such treatment is certified by the interstate sanitary officer, or the State or other health authority within whose jurisdiction it is obtained.

SEC. 16. Common carriers operating vessels in commerce between the several States and Territories or the District of Columbia, for passengers in interstate traffic, shall not supply for the use of said passengers any water taken from a lake or stream over which the vessel is being navigated unless the same is certified by the United States Public Health Service or the State or municipal health authority within whose jurisdiction it is obtained as conforming to the bacteriological standard for drinking water promulgated by the Secretary of the Treasury under date of October 21, 1914: *Provided,* That water in regard to the safety of which a reasonable doubt exists may be used if the same has been treated in such manner as to render it incapable of conveying disease, and the fact of such treatment is certified by the aforesaid health authority or by the Surgeon General of the United States Public Health Service or his accredited representative.

Following the promulgation of the above-quoted interstate quarantine regulations and in order to facilitate their enforcement, the continental United States was divided into 12 districts known as interstate sanitary districts. The district of the Great Lakes embraces that portion of the United States lying north of a line beginning at the junction of the seventy-fourth degree of longitude and the Canadian line, and extending south to the forty-second degree of latitude, west to the seventy-eighth degree of longitude, south to the fortieth degree of latitude, west to the ninetieth degree of longitude, north to the forty-sixth degree of latitude, west to the ninety-third degree of longitude, and north to the Canadian line.

The above-described district embraces parts of the States of New York, Pennsylvania, West Virginia, Ohio, Indiana, Illinois, Wis-

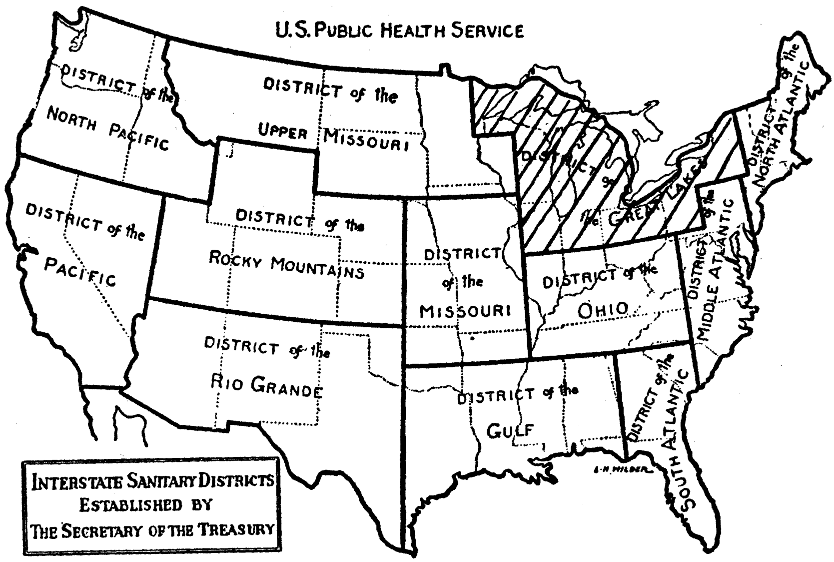

FIG. 1.—Map showing interestate sanitary districts. District of the Great Lakes indicated by diagonal lines.

consin, Minnesota, and the entire State of Michigan. (See fig. 1.) The headquarters and laboratory for this district are at the United States Marine Hospital, 4141 Clarendon Avenue, Chicago, Ill. During the past summer, inspections were made and samples collected from most of the passenger vessels and from some freight vessels on the Great Lakes, the scope of this work being outlined below.

Present Method of Obtaining Drinking Water on Lake Vessels.

Of the two general methods of obtaining drinking water on board lake vessels, the first and most common is by pumping, or by gravity, through a sea cock in the hull of the vessel, and the second by filling the drinking water tanks through a hose from a hydrant on shore.

Sea cocks.—A sea cock consists generally of a flanged valve bolted directly to the shell of the vessel, the water entering the cock through numerous small holes piercing the shell. These holes act as a strainer to prevent solid matter entering the valve. The cocks vary in size from 2 to 10 inches, and are usually placed at a depth of about 8 feet below the water level.

From the sea cock the water is distributed by several methods. In a great many cases the storage tanks are located below the water line, and it is possible to fill them by gravity directly from the sea cock. In other cases the water is pumped into the tanks by the general service pump. A few vessels are equipped with special pumps which are used only for handling fresh water, and on these vessels the tanks are filled with this pump. In the first and last methods it is quite common to find special sea cocks used only for taking in the drinking water supply. In a number of cases, however, the tanks are filled by gravity from the general service sea cock.

Drinking-water storage tanks.—The drinking-water storage tanks well aft, and sometimes in both places. The tanks are usually cylindrical in shape, varying from 3 to 5 feet in diameter, and from 10 to 20 feet in length, and are constructed of heavy galvanized iron or sheet steel. In a few cases, tanks are built in the fantail of the vessel by placing a bulkhead across the ship and allowing the hull to form part of the tank. Such construction is faulty, difficult of access, and in many cases potentially subject to contamination. In two tanks of this type, soil pipes from water closets were found to pass through the tanks, the outlets being bolted to the hull plates. In one of these latter tanks, there was also found to be leakage around the rudder post with consequent contamination. The cover of these tanks consisted of wooden decking, which in some cases was rotted, allowing leakage from near-by poorly kept urinals. These conditions were corrected without delay.

Very few tanks are lined, though sometimes they are coated with "bitumastic enamel," or are given a wash coat of neat cement.

The water of the Great Lakes contains very little sediment, and hence it is unnecessary physically to clean the tanks except at very long intervals. During the summer, pending our investigations, directions were given several freight vessels for disinfecting the tanks with hypochlorite at intervals for the remainder of the season, in lieu of having a man go inside the tank and scrub it, which would most likely increase the contamination rather than lessen it.

Distributing systems.—On most vessels there are two, and in some cases three, systems of water supply: First, the fresh or drinking water which supplies drinking fountains, kitchens, and washbasins; second, the so-called "sanitary" system, which furnishes the water

for flushing toilets; third, the fire system, which is also often used for washing down decks and other purposes. As far as sanitary significance goes, the drinking-water system is the only one under consideration.

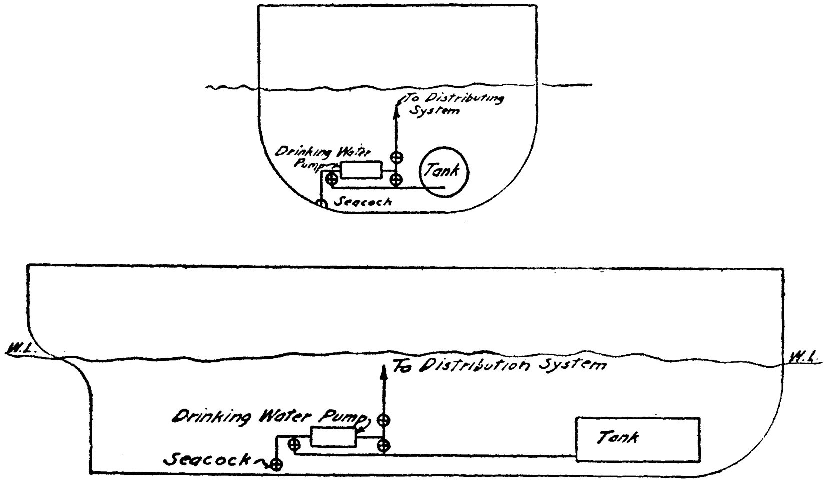

FIG. 2.—Tank filled from seacock by gravity or by special drinking-water pump. Water distributed by special drinking-water pump.

This water is distributed either by gravity from a storage tank located on an upper deck or by a special distributing pump which maintains a constant pressure in the system. When the tanks are filled by gravity from the sea cock there is always a special distributing pump which takes the water from the tanks. (See fig. 2.)

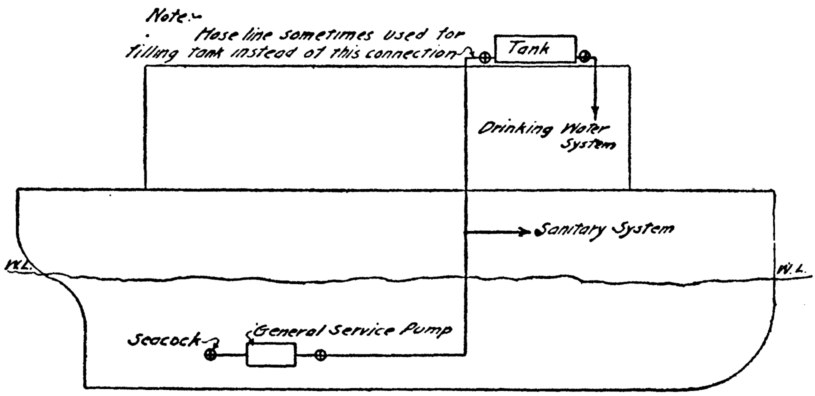

FIG. 3.—Tank filled from seacock by general service pump. Drinking water distributed by gravity.

When the tanks are filled by the general service pump the water is either distributed by gravity or by a special pump. (See fig. 3.) When a special pump is used for filling the tanks the water is usually distributed by this same pump, although in some cases it may

supply a tank on the upper deck from which the water is distributed by gravity. (See fig. 4.)

The greatest opportunity for the contamination of the drinking-water supply occurs when the tanks are filled by the general service pump. It is customary for the general service pump to be used in port for washing down decks, and upon leaving port for "shooting" ashes, after which the drinking-water tanks are filled, the idea being that during the time taken for "shooting" ashes the sea cock, suction pipe, and manifold are thoroughly cleansed by the force of this flushing. Inasmuch, however, as on some vessels the suction pipe is 8 inches in diameter and 50 feet long, besides containing numerous bends, it is obvious that there is a considerable opportunity for polluting matter to remain in this pipe, even after running the pump in clean water for some time. (See figs. 5 and 6.)

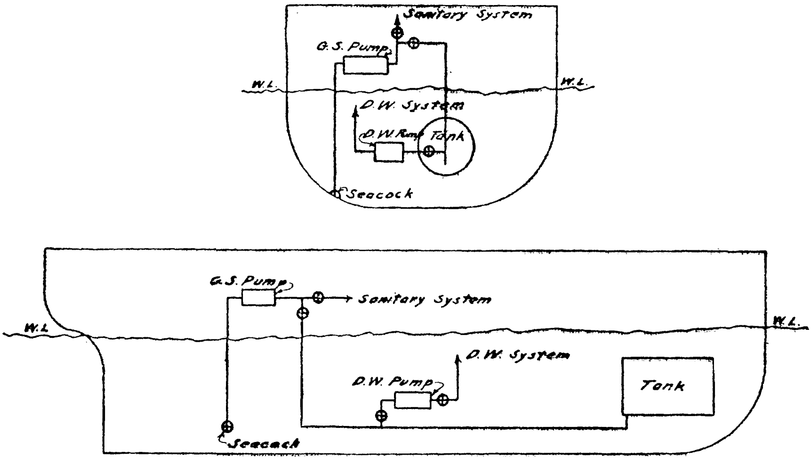

FIG. 4.—Tank filled from seacock by general service pump. Drinking water distributed by special pump.

Where a special pump is used for filling the tanks, water is pumped through the sea cock only when the vessel is well out in the lake. In a great many cases, however, the sea cock itself is left open all the time, and a valve on the suction line near the pump is opened or closed as water is taken in. This means that the suction line is filled with water at all times. Therefore, when the vessel is lying in port the water in the suction line becomes contaminated. The location of the docks at practically every port on the Great Lakes is such that the vessels lie in very badly polluted water. At Chicago a majority of the boats tie up in the Chicago River below the outlets of several large sewers. At Milwaukee the docks are on the Milwaukee River, which contains an excessive amount of sewage pollution, being, in fact, "septic" most of the time. At Buffalo the docks are on the Buffalo River, where the conditions are worse than

at Milwaukee. At Detroit the docks are along the Detroit River and closely adjacent to many large sewer outfalls. At Cleveland some vessels still dock in Cuyahoga Creek, which is always "septic." The Detroit & Cleveland Navigation Co. and the Cleveland & Buffalo Transit Co., which enter Cleveland, dock at a new pier inside the breakwater, but the water at this point is also contaminated.

On some vessels, in order to protect the drinking-water supply from pollution of this kind, a valve has been placed on the suction line about 3 feet from the fresh-water sea cock, and between this valve and the sea cock a small drainpipe is tapped, controlled by another valve. When not pumping through the sea cock, both the sea cock and the extra valve are closed and the small drainpipe is opened. This prevents the entrance of any contaminated harbor water, since

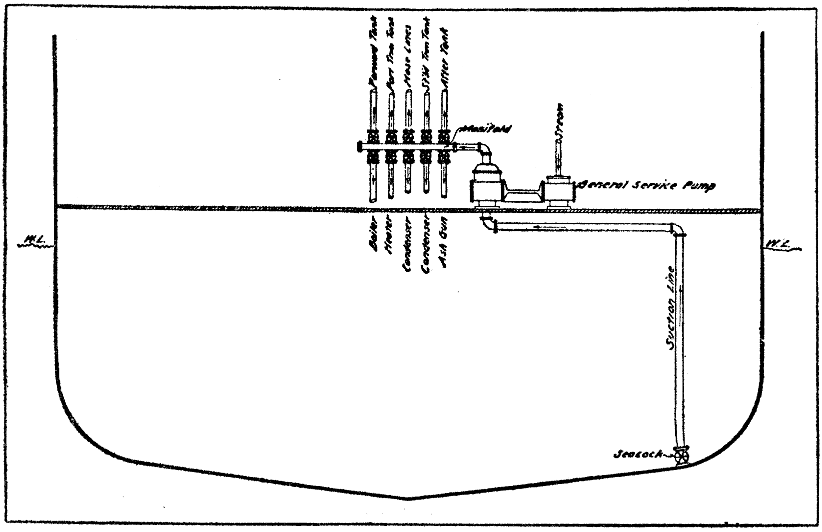

FIG. 5.—Cross section of vessel, showing seacock suction line and manifold.

even if the sea cock leaks the leakage will drain out into the bilge through the small open valve.

By reference to the diagrammatic sketches, figures 2, 3, and 4, the general scheme of obtaining water as outlined above can be seen.

On some vessels where drinking water is distributed from an upper deck tank by gravity this tank is connected directly to the pump by a pipe, or the tank is filled from a hose. (See fig. 3.) This arrangement is preferable, because there is no possibilty of water being pumped into the drinking-water tank except when it is specifically intended to do so. That this matter is important is borne out by the fact that at times, through negligence, water is pumped into the tanks when lying at dock, because the system of opening up the pipe line

to the drinking-water tanks when the vessel is passing through a zone of uncontaminated lake water carries with it the possibility, even the probability, of carelessness and forgetfulness in leaving open the valve after the vessel has entered polluted water. It has been stated that a number of times these valves have been left open and the pump has been kept running after vessels had entered the Chicago and Milwaukee Rivers. Employees aboard lake carriers are just as liable to forget as other persons. That this particular act is ever intentional is unlikely, but there is reason for the belief that this accident has happened a number of times. One of the writers (Letton) during the past season while inspecting a vessel found the gravity tank filled with polluted Chicago River water because of the carelessness of the watchman in opening the valve leading to the tank while washing down decks. And even if the duty of collecting drinking water is performed with vigilance, such care can be, and most likely often is, nullified by leaky valves, the defects of which can not be detected except by means of the drip valve described above.

Filling tanks from shore.—When drinking-water tanks are filled from shore, this is done either by carrying the water through a fire hose directly from the hydrant to the tank or by connecting the hose to the distribution system. In most cases vessels that fill their tanks from shore have the pipe systems so arranged that they can also fill through a sea cock directly from the lake, protecting this line from contamination with the valves and drip pipe previously described. As a further protection on some vessels the wheels for operating the valves are removed, as shown in figure 6, so that there shall be no accidental opening of this connection.

Opportunities for contamination.—The opportunities for contaminating the drinking water aboard lake carriers are as follows:

1. Contamination of sea cock or suction pipe while lying in polluted water, due to faulty seating of valves, failure to close valves, or the use of a general service pump.

2. Since in most of the vessels the engine rooms and sea cocks are aft of amidships and since there is usually more or less sewage discharged from toilets in the forward part of the boat, it is possible that some of this fecal matter discharged from the bow is sucked in through the sea cock.

3. Accidental or intentional taking of supplies near shore or in unsafe waters. This may occur when the vessel never goes far from shore, as in running between Chicago and Milwaukee, or when it is in clean water for too short a time to fill its tanks. This situation is aggravated by the fact that the engineer in the engine room can not tell at all times exactly where the vessel is; also by the fact that many ship captains and engineers are not acquainted with all the places

where it is unsafe to take water. There is also the likelihood that engineers and other employees may forget to close the sea cock as the vessel approaches a polluted harbor.

4. There is also more or less possibility of picking up sewage in the wake of other vessels, as for example where one vessel is towing another. That this method of contamination is a real one has been brought out by testimony before the International Joint Commission.[1]

Summary.—As a result of the statements made above regarding the taking of a ship's drinking-water supply from the Lakes, it is obvious that it is an impossibility for any vessel operating on the Great Lakes, using the methods at present in vogue, to obtain a drinking water which shall be at all times free from contamination.

It is therefore necessary, in order always to furnish a safe water for drinking purposes, that each vessel shall install some suitable form of water-purification apparatus. Some vessels have already made such attempts. The apparatus used is discussed under the next heading.

Present Methods of Treatment of Water on Board Lake Vessels—Advantages and Disadvantages of Each.

Filtration.—The attempt at water purification most commonly found in use on vessels on the Great Lakes is filtration through small rapid sand filters, there being about 30 vessels using filters of this kind. These filters are used either as the sole means of treatment or as a preliminary step in some other process of purification. The filters vary in size from 10 to 60 inches in diameter. Each filter is equipped with a shunt feed box for adding aluminum sulphate to the water before filtration. (See figs. 7 and 8.)

Filters of the kind above described have an extremely low bacterial efficiency. In fact it is sometimes found that the filter increases rather than decreases the bacterial count. The causes for this inefficiency are many. In the first place, in order to produce efficient results in a rapid sand filter, it is requisite that a coagulant, such as aluminum sulphate, be added to the water in order to form a layer on the surface of the filter sand which will strain out the bacteria, suspended matter, and other impurities. It is also necessary that a certain period elapse between the adding of the coagulating chemical and the passage of the water to the filter, because of the time required for the completion of the chemical reaction. If this necessary time is not given, the coagulation will take place for the most part throughout the filter body and perhaps in the filtered

[1] Hearings of the International Joint Commission on Remedies for the Pollution of Boundary Waters Between the United States and Canada, pp. 225–285.

water. In filters of the above type, the water receives the chemical on entering the filter, so that no time is allowed for coagulation. This system of adding the coagulant was found to be very unreliable, because there is no simple method for determining when the chemical is exhausted. During inspections of vessels having filters, statements made by the engineers showed that the periods between refilling the chemical tank varied from one week to once a season. Probably 10 or 15 boxes were examined at the time of inspection and in none of them was any chemical found.

The question of the rate of filtration introduces another cause of inefficiency. There is no method of preventing the rate being whatever the capacity of the pump supplying the filter makes it. As a result loads far in excess of their rated capacity are undoubtedly put upon these filters. Then, again, the rate varies widely, this fluctuation greatly tending to allow foreign matter to penetrate the sand body. Another disadvantage of filters, as found on lake carriers, is that for some time after washing, unless they are allowed to filter to waste for a considerable period, there will be a decided increase in the bacterial count. Therefore, it is believed that the ordinary small pressure rapid sand filter, with the alum shunt feed, without auxiliary sterilizing apparatus, is dangerous rather than beneficial to a vessel, owing to the fact that it gives false security.

On two vessels there are sand filters of a type somewhat different from that described above. In this apparatus the water first passes between a series of iron plates so connected with an electric current as to form electrodes. The action of this electrode box is to cause a precipitation of iron hydrate, which is a good coagulant and one easy to remove by filtration. From the electrode box the water passes to a small coagulating chamber, where some time is given for the coagulant to collect and partly settle. From this coagulating chamber the water passes through two small rapid sand pressure filters, connected in series. The apparatus is arranged to act automatically, so that the electric current is on only when water is being drawn through the system. It is so designed that the filters can be washed one at a time, the wash water being furnished by the filter in operation. While the results given by this apparatus are somewhat better than those from the type first described, there are still a number of defects which result in a poorly filtered water during a considerable portion of the time.

Ultra-violet ray sterilization.—Thirteen boats operating during the past season were equipped with apparatus for sterilizing their drinking water by ultra-violet rays. Eleven of these vessels used a "pressure-type" apparatus and two a "gravity-type." The pressure type of apparatus consists of a cast-iron cylindrical shell, with a quartz tube

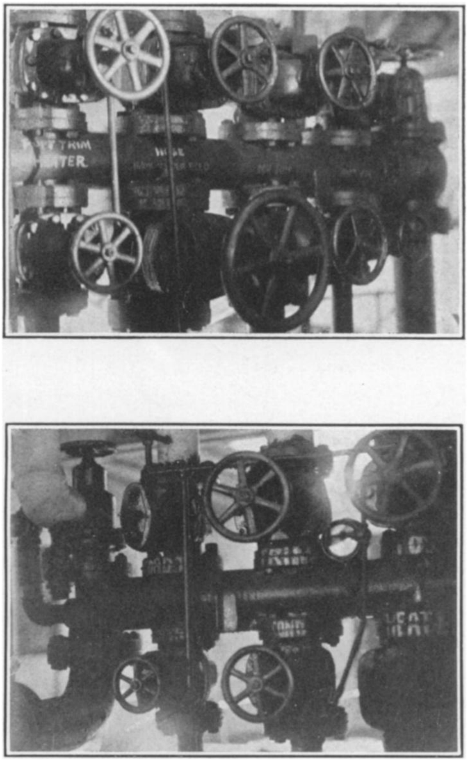

FIG. 6.—PHOTOGRAPHS OF MANIFOLDS ON TWO VESSELS. LOWER PHOTOGRAPH SHOWS WHEEL ON VALVE CONTROLLING LINE LEADING TO FORWARD TANK REMOVED. DRAIN VALVE FOR DETECTING LEAKAGE CAN BE SEEN ABOVE THIS VALVE.

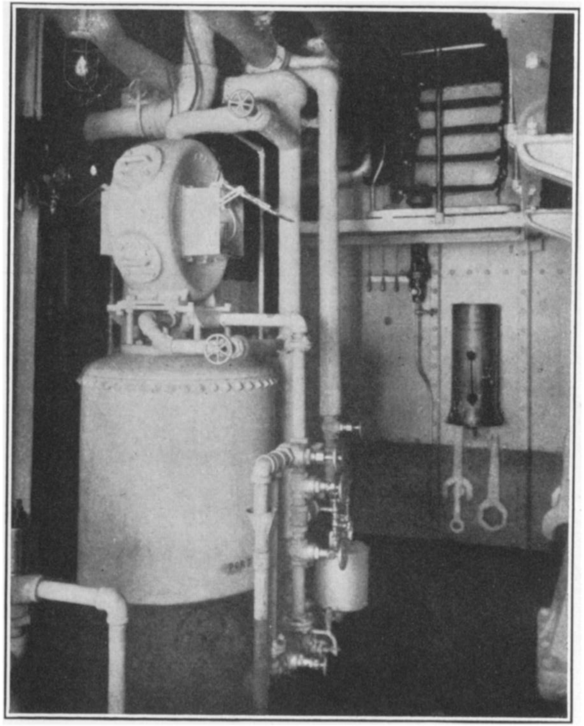

FIG. 7.—VESSEL EQUIPPED WITH RAPID SAND FILTER WITH SHUNT FEED COAGULANT BOX AND PRESSURE TYPE ULTRA-VIOLET RAY APPARATUS.

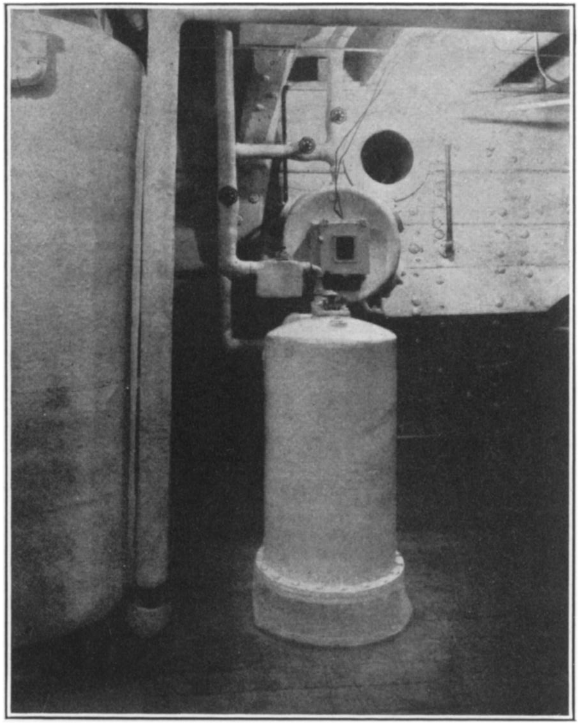

FIG. 8.—VESSEL EQUIPPED WITH RAPID SAND FILTER WITH SHUNT FEED COAGULANT BOX AND PRESSURE TYPE ULTRA-VIOLET RAY APPARATUS.

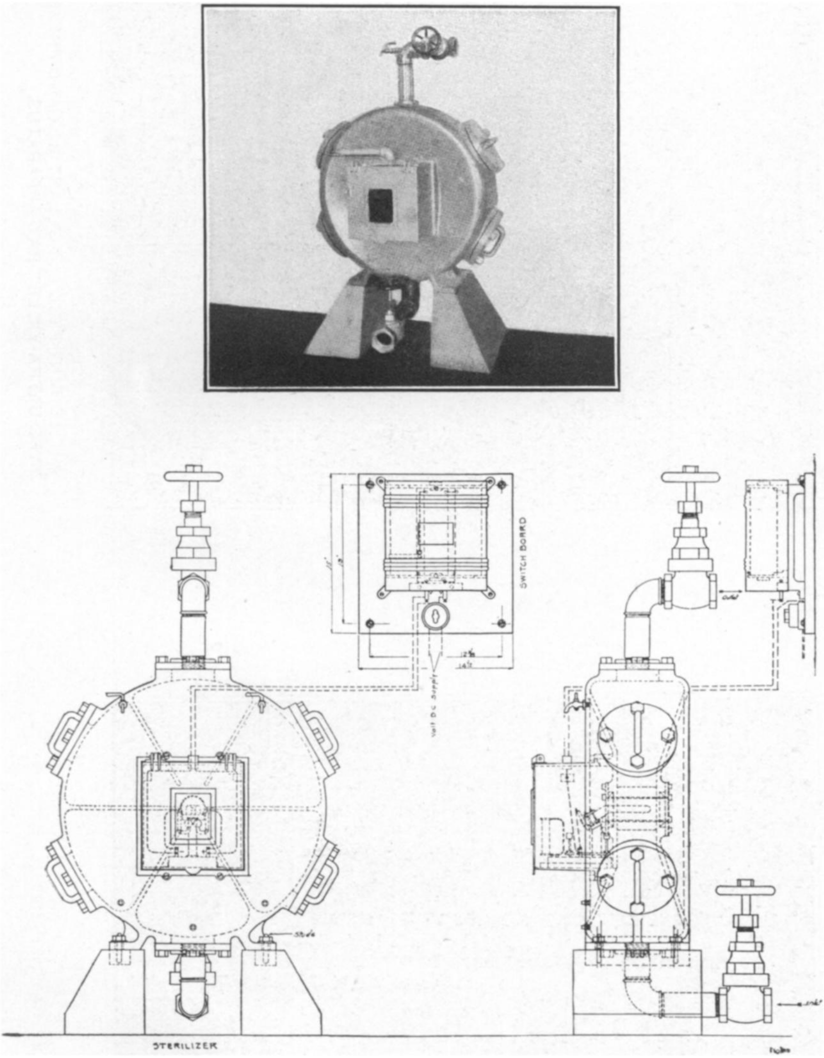

FIG. 9.—PHOTOGRAPH AND DRAWING OF ULTRA-VIOLET LIGHT STERILIZER OF THE PRESSURE TYPE. THIS APPARATUS USES THE PISTOL TYPE OF LAMP.

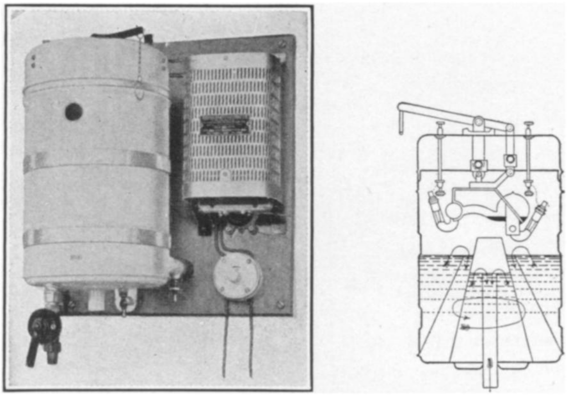

FIG. 10.—PHOTOGRAPH AND DRAWING OF ULTRA-VIOLET LIGHT STERILIZING APPARATUS OF THE GRAVITY TYPE WITH HAND-TILTED LAMP.

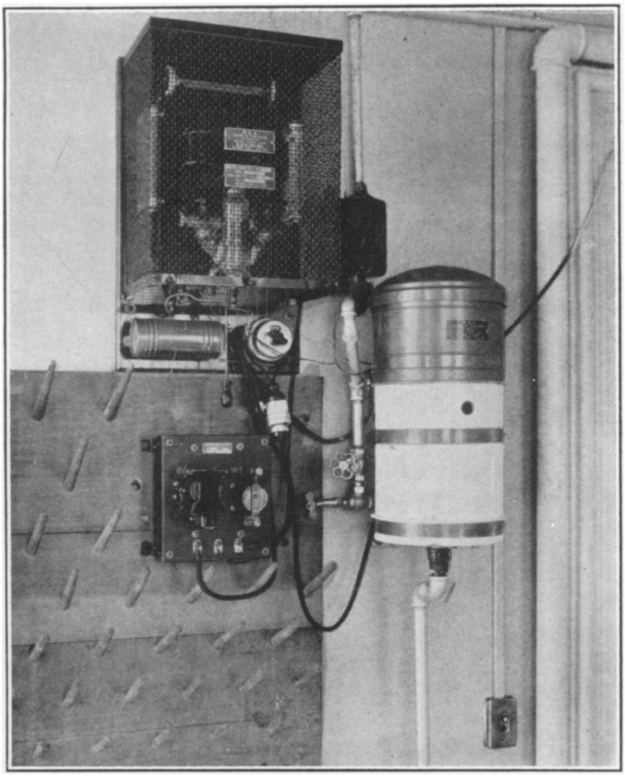

FIG. 11.—PHOTOGRAPH OF ULTRA-VIOLET LIGHT STERILIZING APPARATUS OF THE GRAVITY TYPE EQUIPPED WITH AUTOMATIC TILTED LAMP AND WITH SOLENOID-OPERATED WATER VALVE SO ARRANGED THAT NO WATER CAN PASS THE APPARATUS UNLESS THE CURRENT IS ON AND THE LAMP AT ITS MAXIMUM INTENSITY.

through its axis and containing baffle plates so arranged as to spread the water in a thin film while passing through the ultra-violet field. (See figs. 7 and 8.) The ultra-violet lamp in use during the summer of 1915 was a quartz lamp of the "pistol" type, which was inserted on the inside of the quartz tube, as shown by the accompanying photograph and diagrammatic sketch of the apparatus. (See figs. 7, 8, and 9.) In the gravity type of apparatus the lamp is suspended above a baffled treatment chamber, where the water is exposed in a thin film twice during its passage by the lamp. The gravity apparatus had only a capacity of about 100 gallons an hour, which is considerably below the maximum amount needed on most lake vessels, and as result it was used solely for filling water bottles, pitchers, etc. (See fig. 10.) The pressure apparatus, on the other hand, was rated either at 200 or 1,000 gallons an hour, and the water was treated while under pressure on its way to the distribution system. There were a great many defects in the apparatus in use. In the first place, on all vessels except one the lamp was operated at 110 volts. It is of doubtful possibility to obtain a sufficient intensity of ultra-violet rays at this voltage. In the second place, a sudden fluctuation in voltage of 5 per cent would put out the lamp, the water in the meantime continuing to flow. The last three pressure apparatuses installed, however, contained an attachment for automatically relighting the lamp when the voltage resumed its normal intensity.

This feature of the light going out, with a fluctuation of voltage, is an extremely important one, especially aboard ship. A great many of the vessels do not have an excess in generator capacity, and as a result, throwing in or out of any large amount of current will cause a fluctuation. This is sometimes caused by turning on the searchlight or in operating the wireless. The lamps would also go out when generators were shifted, as is ordinarily done when the vessel comes into port. Another objection to the apparatus is that the lamps are extremely delicate, and unless handled very carefully, will break, and thus put the entire equipment out of commission. It is essential when using ultra-violet rays to have the water clear, as any slight turbidity will considerably reduce their efficiency, due to the fact that a certain number of the bacteria present in the water will be protected by the shadow caused by minutely suspended matter. It is thus necessary to filter water before passing it to the sterilizer in order to remove all turbidity. The filters used in this connection were of the small pressure rapid sand type. As mentioned above, these filters occasionally allow a turbid water to pass. There is a tendency, especially with a hard water, such as the lake waters, for a certain amount of mineral salts to deposit on the quartz tube, such deposits rendering the tube more or less opaque to ultra-violet rays, hence lowering the efficiency of the lamp. Another

objection to the apparatus was that the lamp did not reach its maximum efficiency for 5 or 10 minutes after being started, although the water was passing continuously. This is due to the fact that mercury vapor lamps do not obtain maximum efficiency until they have burned long enough to become well heated.

The ultra-violet type of sterilizing apparatus early attracted our attention. The results of laboratory examinations demonstrated that the apparatus in the form described was inefficient. The company manufacturing the apparatus at once set to work to remedy the obvious defects. They have equipped a new type of lamp with an automatic device for relighting whenever it goes out because of breaks in the current. It is claimed that this new lamp emits a higher per cent of ultra-violet rays, and that it will stand a much greater fluctuation in voltage than the old type without going out. The company has also developed an arrangement whereby the water will be shut off automatically when the lamp is out and remain so until it is relighted and regains its point of maximum efficiency, when the water is again started automatically. (See fig. 11.)

Chlorine disinfection.—The water supply of five vessels was treated with calcium hypochlorite, a small does of a solution of this chemical being added to the storage tank each time it was filled. Calcium hypochlorite, a very efficient sterilizing agent, when properly administered, is not to be recommended on vessels for the reason that it depends for its constant efficiency upon some person to correctly proportion the dosage added to the tanks each time they are filled. On one of the vessels using this chemical the water, at the time of inspection, had an extremely strong chlorinous taste. This indicated an overdose, and was evidence that there was no close control of the amount added. This method is further open to the criticism that its uniform efficiency rests entirely upon human agency, which can never be wholly dependable.

There was installed on one vessel, late in the season, an apparatus for treating the water with liquid chlorine. This appliance did not actually add the chlorine gas to the water, but used it for making up a strong solution of chlorine water. The chlorine gas was passed from a cylinder of liquid chlorine into a large vertical hard-rubber cylinder, displacing water, thus making it possible to obtain a measured amount. This hard-rubber cylinder was connected to a larger cast-iron cylinder, similar in form to a small pressure filter. After the chlorine gas had filled the hard-rubber cylinder, water was turned in at the top and sprayed down through the gas, the water passing out into the cast-iron container. By the time the cast-iron cylinder filled with water, the gas in the hard-rubber cylinder had entirely gone into solution. The water to be treated, after passing a small pressure rapid sand filter, was carried to

the chlorine apparatus, where a constriction was placed in the pipe. Connections between the chlorine water tank and the pipe line were so made that when there was a flow of water in the water pipe there would be a slight proportional shunt feed into the top of the chlorine water tank, causing a displacement, and hence the feeding of a proportional amount of the chlorine water into the pipe line. It was planned that the water displacing the chlorine would remain on top of the chlorine water without mixing to any perceptible degree. As a matter of fact, however, the vibrations and rolling of the vessel were such as to cause mixing, so that the chlorine solution lost strength continuously while in operation.

There are a number of objections to the above-described apparatus. To charge the cylinder with chlorine water requires the opening and closing, in correct sequence, of about 15 valves. This means that the operator must be thoroughly trained before he can be trusted to correctly manipulate the complicated mechanism. The fact that the chlorine solution is constantly becoming diluted is another objection, as it requires careful chemical tests on the treated water to know just when this solution becomes so weak as to be inefficient. Any apparatus for water treatment on board a vessel which requires constant supervision is bound sooner or later to give bad results. The engineer's first duty is to run his engines. The water supply is a secondary consideration. In case of some unexpected trouble in the engine room the water-purification apparatus will be neglected; also any apparatus requiring a considerable amount of skill for its operation is liable to be put out of commission in case of accident to the engineer.

Sterilization by heat from steam jet.—There were five vessels which treated the drinking water by heating with a steam jet. This scheme was devised by the Detroit city board of health in connection with their study of drinking water on vessels entering Detroit.

To operate this apparatus, water was pumped from the sea cock by means of an ordinary steam-boiler injector, and when discharged from the injector it was raised to a temperature of about 160° F. After leaving the injector, a steam jet was added to the line, further increasing the temperature to about 230° F. In this discharge line was placed a thermometer, and upon starting, the water was allowed to run to waste until the last-mentioned temperature was reached, at which time the waste line was closed and the water passed through several hundred feet of pipe placed inside a cylindrical tank through which cold water was circulated. This cooling tank reduced the temperature to about 130° F. From the cooling tank the water was run into the drinking-water storage tanks.

This apparatus, while able to produce good results under careful management, was liable to be mishandled. In the first place, it depended entirely upon the observation of the engineer as to the reading of the thermometer in order to be certain that no water reached the storage tanks which had not been heated to the above-named temperature, and as the water after heating was passed immediately to the cooling tank, it was not held at the high temperature except for comparatively a few seconds.

With a few modifications, the apparatus could be made "fool proof" and automatic in its operation. These improvements consist in adding a supplementary tank, in which the hot water could be stored for perhaps five minutes before entering the cooling tank. It would also be possible to install a thermostat just beyond this retention tank, which would automatically control a waste valve and a valve leading into the cooling tank, so that unless the water leaving

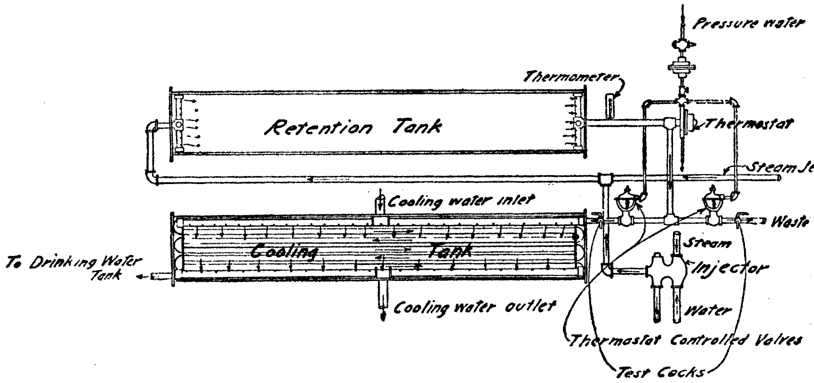

FIG. 12.—Drawing of apparatus for disinfecting water by steam jet, equipped with devices to make it automatic and foolproof in operation.

the retention tank was up to the required temperature, it would run to waste. Figure 12 shows this apparatus with the suggested modifications. As in use during the past summer the retention tank was omitted, as was the thermostat, and in place of the thermostat-controlled valves hand-operated valves were used.

Results of bacteriological examinations.—All examinations made at the laboratory were strictly in accordance with the Treasury Department bacteriological standard of purity for drinking water for interstate common carriers, this maximum limit of permissible bacteriological impurity being:

1. The total number of bacteria developing on standard agar plates, incubated 24 hours at 37° C., shall not exceed 100 per cubic centimeter: *Provided*, That the estimate shall be made from not less than two plates, showing such numbers and distribution of colonies as to indicate that the estimate is reliable and accurate.

2. Not more than one out of five 10 c. c. portions of any sample examined shall show the presence of organisms of the *Bacillus coli* group when tested as follows:

(*a*) Five 10 c. c. portions of each sample tested shall be planted, each in a fermentation tube containing not less than 30 c. c. of lactose peptone broth. These shall be incubated 48 hours at 37° C. and observed to note gas formation.

(*b*) From each tube showing gas, more than 5 per cent of the closed arm of fermentation tube, plates shall be made after 48 hours' incubation, upon lactose litmus agar or Endo's medium.

(*c*) When plate colonies resembling *B. coli* develop upon either of these plate media within 24 hours, a well-isolated characteristic colony shall be fished and transplanted into a lactose broth fermentation tube, which shall be incubated at 37° C. for 48 hours.

For the purposes of enforcing any regulations which may be based upon these recommendations the following may be considered sufficient evidence of the presence of organisms of the *Bacillus coli* group:

Formation of gas in fermentation tube containing original sample of water (*a*).

Development of acid-forming colonies on lactose litmus agar plates or bright red colonies on Endo's medium plates when plates are prepared as directed above under (*b*).

The formation of gas, occupying 10 per cent or more of closed arm of fermentation tube, in lactose peptone broth fermentation tube inoculated with colony fished from 24-hour lactose litmus agar or Endo's medium plate.

These steps are selected with reference to demonstrating the presence in the samples examined of ærobic lactose fermenting organisms.

3. It is recommended, as a routine procedure, that in addition to five 10 c. c. portions one 1 c. c. portion and one 0.1 c. c. portion of each sample examined be planted in a lactose peptone broth fermentation tube in order to demonstrate more fully the extent of pollution in grossly polluted samples.

4. It is recommended that in the above-designated tests the culture media and methods used shall be in accordance with the specifications of the committee on standard methods of water analysis of the American Public Health Association, as set forth in "Standard Methods of Water Analysis" (A. P. H. A., 1912).

A total of 961 samples was collected and examined during the past summer from 74 different passenger vessels, and 68 samples were collected and examined from 33 different freight vessels. These samples were for the most part collected at Chicago and examined as soon as they reached the laboratory. Samples were also collected from vessels at Buffalo, Cleveland, Detroit, and Milwaukee, and shipped on ice by express to the laboratory. These latter samples generally reached the laboratory within 24 hours after shipment, although in some cases it required 48 hours. Most of these outside samples were collected at Detroit, where very material aid was rendered by the local board of health which had already inspected and examined the water supplies of all vessels running out of Detroit.

A series of vessels equipped with various types of purification apparatus were selected for intensive study. From these vessels, a great many samples were collected at various points in the purification systems in order to determine the efficiency of the apparatus.

The following table outlines the results obtained on both passenger and freight boats:

Results of analyses of tap samples from passenger and freight boats.

	Samples examined for total bacteria and B. coli.			Samples examined for total bacteria.			Samples examined for B. coli.		
	Total number.	Number conforming.	Per cent conforming.	Total number.	Number conforming.	Per cent conforming.	Total number.	Number conforming.	Per cent conforming.
Passenger boats:									
Without treatment	156	35	22.4	156	55	35.2	163	78	47.8
With treatment	521	206	39.6	524	338	64.5	550	322	58.5
Rapid sand filters only	213	83	38.9	211	144	68.2	223	118	52.8
Electric rapid sand filters	13	5	38.5	13	7	53.7	13	10	76.9
Ultra-violet rays	240	74	30.8	241	137	56.8	256	139	54.3
Heat treatment	13	9	69.2	16	12	75.0	12	12	100.0
Calcium hypochlorite	5	3	60.0	5	3	60.0	7	7	100.0
Liquid chlorine	38	32	84.2	38	35	92.2	39	36	92.3
Freight boats:									
Without treatment	57	11	19.3	57	22	38.5	60	28	46.7

This table, which includes only tap samples, shows that the methods of purification in use at the present time are very inefficient, less than 40 per cent of the samples conforming to the standard. There is but a slight difference between the results on passenger boats having no treatment and freight boats, which are without treatment, 22.4 per cent of the samples from passenger boats conforming to the standard, and 19.3 per cent of the samples from freight boats conforming.

When the results of the samples receiving treatment are separated according to the form of treatment, it is seen that the two methods most commonly used give very inefficient results. Samples treated in rapid sand filters conform only 38.9 per cent of the time, and samples treated by ultra-violet rays in connection with rapid sand filters conform only 31 per cent of the time. This drop in efficiency in connection with the ultra-violet apparatus was probably due to the fact that vessels so equipped ran in worse water than those having filters only.

Only a comparatively few samples from boats using heat treatment were taken, but these show that 69.2 per cent of the time the samples conformed to the standard. All the samples from these boats conformed according to *B. coli*, the failure to conform being due to high counts. As pointed out under the discussion of this type of apparatus, the high counts were undoubtedly due to the fact that the water after treatment was passed into the storage tanks at a temperature above that of the body, and hence there was multiplication of the 37 degree bacteria. The *B. coli* were killed by the treatment.

Those boats using hypochlorite for disinfection conformed 60 per cent of the time, but as only five samples were collected from boats

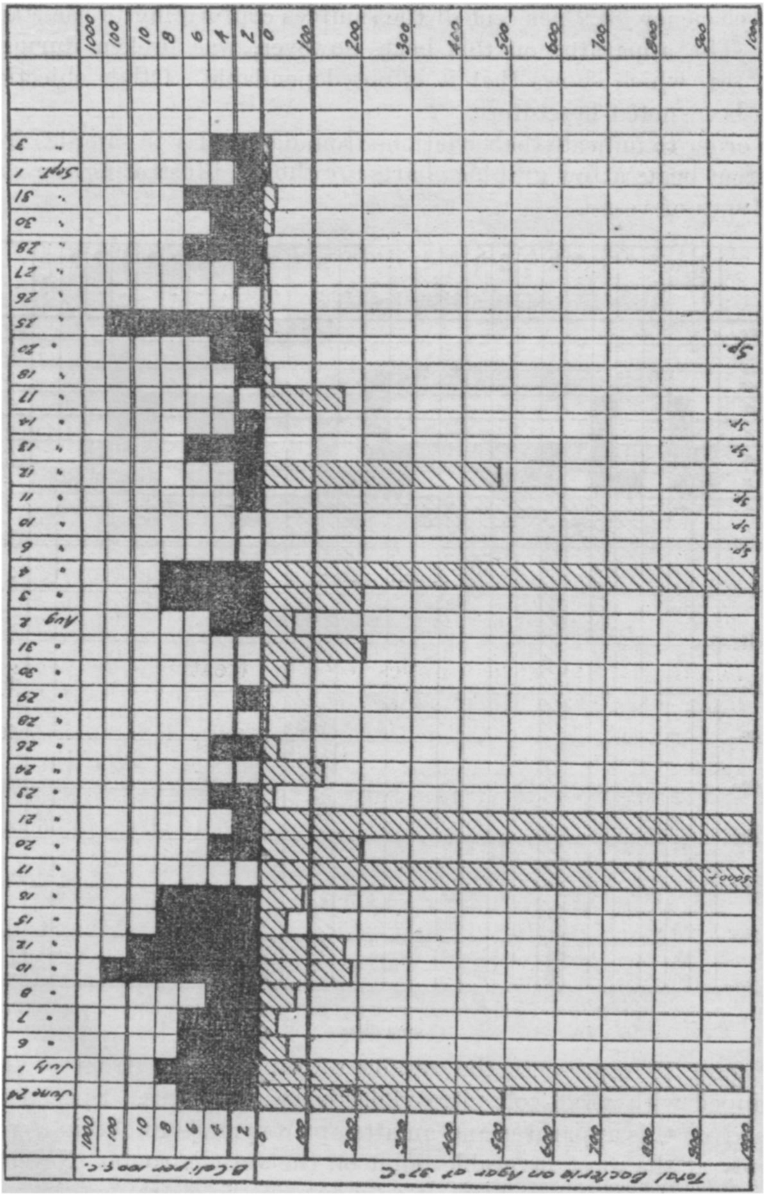

FIG. 13.—Graphic chart showing results of analyses of tap samples from steamship equipped with ultra-violet ray apparatus.

of this type, no reliable conclusion can be drawn as to the constant efficiency of this treatment.

The samples from the one vessel using liquid chlorine show a high efficiency, 84.2 per cent of the samples conforming to the standard. The apparatus on this boat, however, was broken during a high sea, which shows that it is not dependable. Other objections have been noted heretofore.

In order to indicate the variations from day to day in samples from different boats a few graphic charts are shown, illustrating the various types of vessel.

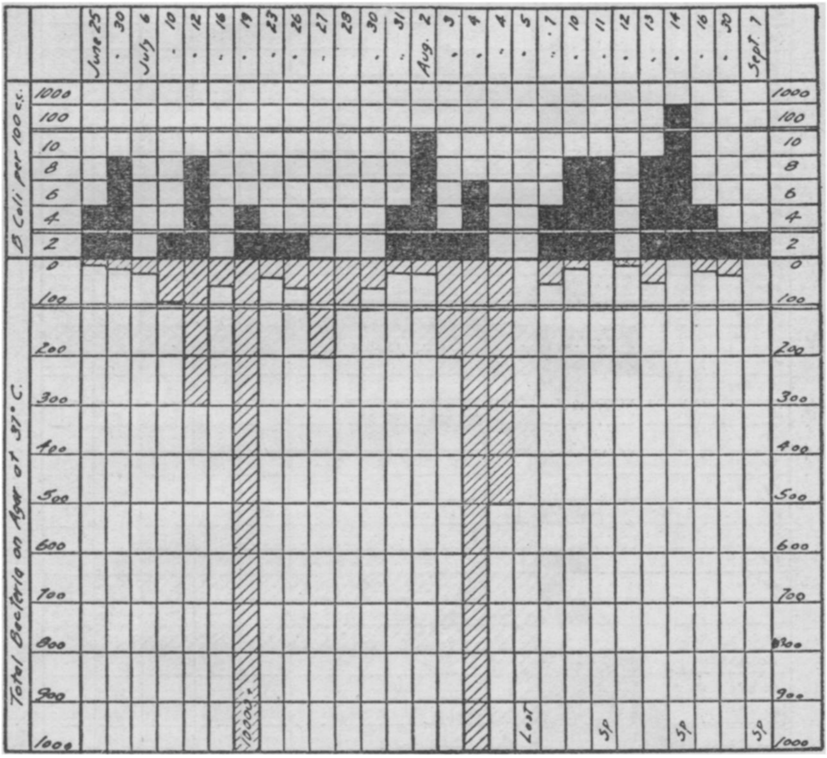

FIG. 14.—Graphic chart showing results of analyses of tap samples from steamship equipped with rapid sand filter.

Figure 13 represents the results of tap samples from a vessel equipped with a 220-volt ultra-violet lamp apparatus. Special care was given this apparatus and an attempt was made to obtain a water supply at the most favorable point on the vessel's route. Nevertheless, poor results were obtained as shown in the chart.

Figure 14 represents the analyses of tap samples from a vessel equipped with a rapid sand filter.

Figure 15 represents the results from three vessels which treated the water with small rapid sand filters. The charts speak for themselves.

A study of the results from different vessels in connection with the type of sea cock and arrangement used for taking on water shows that the arrangement has a very small effect upon the character of water obtained. It is, however, hard to believe that fairly good

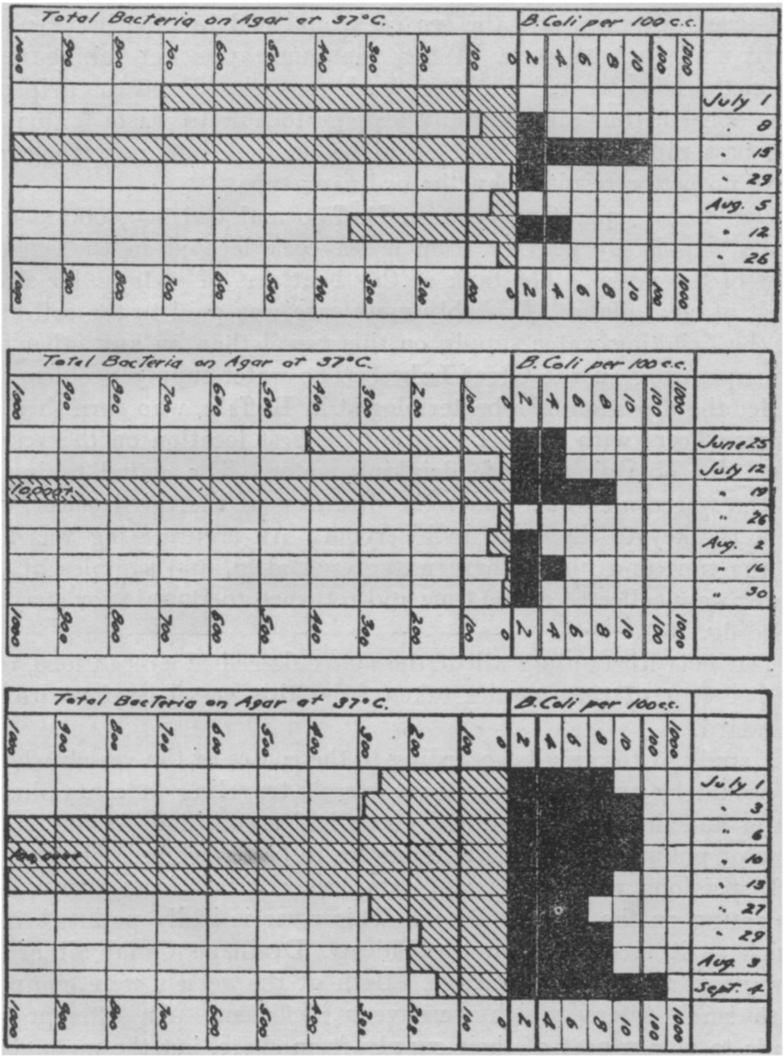

FIG. 15.—Graphic chart showing results of analyses of tap samples from steamships equipped with pressure sand filters.

results were recorded from vessels that obtained the drinking water supply through such piping systems as shown in figures 5 and 6. On these vessels the water is pumped from the sea cock through 50 or 60 feet of 6 or 8 inch piping. That fecal matter is frequently awash

in these pipes can not be denied. Such a condition is intolerable and demands prompt correction.

In order to eliminate the probability of contamination through leaky valves, other vessels used a separate sea cock and special pump for filling the tanks, taking the added precaution to place a valve between the pump and the sea cock, and a drip pipe between this valve and the sea cock. When the pump was not taking water from the lake, the valve and sea cock were closed and the drip pipe was opened, thus allowing any leakage to flow to waste. This was the best piping system that could be devised, but, nevertheless, it gave no better results than the ordinary type.

One vessel, operating between Buffalo and Chicago, obtained its water supply by gravity from a sea cock located in the extreme bow of the vessel. The tank of this boat was of rectangular shape, built of steel plates. Probably more care was paid to the collection of the drinking-water supply on this vessel than on any other carrier operating on the Great Lakes. The water-supply problem was under the direction of a bacteriologist in Buffalo, who furnished the ship's officers with a chart showing the best location on the vessel's route for obtaining a safe drinking water. The actual taking on of the water was done under the direction of the third officer, who kept the key to the valve in his room. An accurate log was kept of the time and place where water was taken, and samples of this water were collected at the time and returned to Buffalo for anaylsis. (See fig. 16.)

Yet, notwithstanding all of the above-described precautions, only 50 per cent of the samples taken from this vessel conform to the standard.

A study of the results according to the routes of the vessels, shows, as would be expected, that those vessels traveling in contaminated water and docking at polluted ports, had a considerably higher degree of pollution than vessels running in better water.

Inspections were made and samples collected from two vessels operating on the Illinois River. This river is badly polluted, inasmuch as it receives from the Chicago Drainage Canal all of the sewage of the city of Chicago. Both of the vessels were equipped with small filters, which were very inefficient. An attempt was made to obtain part of their supply from shore, but the methods of handling this water were so crude that all samples showed a high degree of contamination. Judging from statements made by owners of these vessels, conditions aboard other river boats are as bad if not worse. There is on record a severe epidemic of typhoid fever among the crew and passengers of a Mississippi River boat.

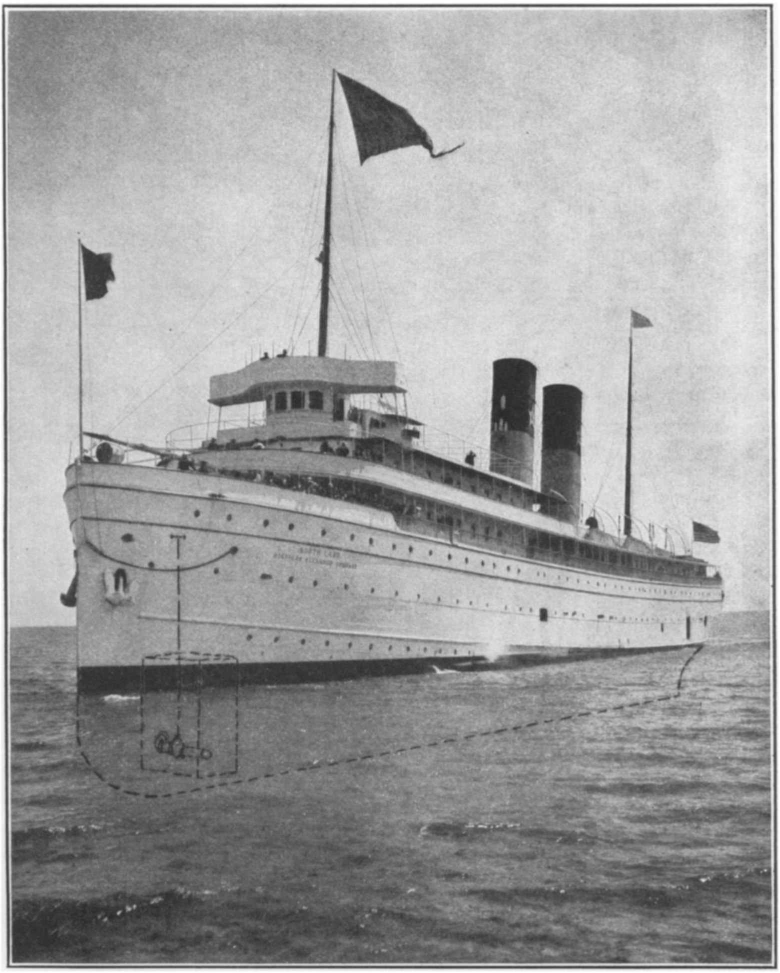

FIG. 16.—PHOTOGRAPH OF STEAMSHIP, SHOWING BY DOTTED LINES ARRANGEMENT FOR FILLING DRINKING-WATER TANK.

Conclusions.

The types of purification apparatus in use on vessels of the Great Lakes at the present time are woefully inefficient. There is not a method in use that can be depended upon to deliver a safe water at all times.

The route and docking place of the vessel play some part in the character of the water supply.

It is impossible, without treatment, to obtain a drinking water for boats directly from the lakes through the present piping systems that will at all times conform to the Treasury Department standard.

Therefore, to comply with the law, it will be necessary for every vessel on the Great Lakes to install a method of water purification which shall be so constructed that it can not under any conceivable circumstances deliver a water which will not conform to the Government requirements. This will necessitate an apparatus that will be entirely automatic in action and proof against carelessness, indifference, and forgetfulness, as well as dependable in every stress of weather.

In order to enable the transportation companies to meet the above requirement a study has been made of all water purification processes which might be capable of adaptation for use on lake carriers. Many conferences have been had with manufacturers of various types of apparatus, and in several cases experimental plants have been installed at this laboratory for testing.

Undoubtedly, the ideal form of water-purification apparatus which will meet the above requirements is the still. This is the only type of apparatus that does not depend in some way on moving mechanical parts for its efficiency, and hence requires but little care for its successful operation. If the scale is not removed from the heating coil at intervals the capacity will be reduced, but this will not effect in any way the quality of the water. Automatically operated water stills are now on the market which produce bacteriologically pure water. At the present time, stills or evaporators are in use on practically all ocean-going vessels, producing a satisfactory drinking water from salt water. There is, therefore, no reason why these stills are not applicable to lake vessels.

One of the main advantages of the use of a still is the fact that no attention need be paid to the place of taking water.

There are but three disadvantages to stills, and these are not of sanitary significance, namely, (1) the operating cost, (2) the possibility of producing a flat or unpalatable water, (3) the possibility of corrosion of pipes or tanks.

Stills which produce a palatable and satisfactory drinking water have been tested at this laboratory. Any still which is so constructed

that it is impossible for the raw water to gain access in any manner to the distilled water will be satisfactory for use on lake vessels. There is no objection, so far as the Government is concerned, to the use of the condensed heating steam for augmenting the supply of distilled water, the only disadvantage of this being the fact that in some installations there is a chance that offensive tastes or odors may be given to the water.

A rigid investigation has demonstrated that the two following-described methods of purification, viz, heating by steam jet or exposure to ultra-violet rays, are capable of producing a satisfactory water, the constant efficiency of each method, however, depending upon the uninterrupted action of moving mechanical parts. As long as these operate in a normal manner good results can be obtained. This means that closer supervision will need to be paid to the operation of these types of apparatus than to the still.

The scheme heretofore outlined in the body of this report of pumping water by means of a steam injector would also be satisfactory, provided that the modifications mentioned were made part of the apparatus. The equipment should consist of an injector for pumping the water, a steam jet for increasing its temperature, a retention tank, holding about five minutes' supply, a thermostat operating a waste valve and a valve leading into the cooling tank, two telltale cocks for enabling the engineer to see that the apparatus is working properly, a thermometer on the line leading into the cooling tank, and a cooling tank for reducing the temperature of the water to somewhere near that of the lake water. (See fig. 12.) One of the main advantages of this method of water purification is that it would not be expensive to install, and that its method of operation would be understood perfectly by the engineer in charge. With this apparatus it would be necessary for the same care to be used in selecting the place of taking in the water that is now used in order to prevent any possibility of bad tastes or odors.

The company manufacturing the ultra-violet ray outfit has installed at this laboratory three different types of apparatus, and these have been thoroughly tested. The results of these tests show that with the improved form of lamp and with the other attachments which will be described, working in a proper manner, that a water meeting the Government requirements can be produced. Where the ultra-violet rays are used there should be installed a pressure regulator, an orifice incapable of being changed; a pressure rapid sand filter, with an alum shunt feed box for adding coagulant of such a size that it will not need to operate at a greater rate than 3 gallons per square foot of filtering area a minute; a suitable arrangement for passing the water through the field of ultra-violet rays; a mercury vapor quartz lamp, operating at 220 volts; an arrangement for pre-

venting the passage of any water except when the lamp is lighted and at its maximum intensity; a device for automatically lighting the lamp when the current is turned on; a simple method of removing and cleaning the quartz tube; and a closed reserve tank, holding, say, 200 gallons, placed upon an upper deck in order to supply the system when the water is shut off. With an apparatus as specified above, all that it would be necessary for the engineer to do would be to turn on the current and furnish the water; after that the apparatus would operate automatically.

With any of the above approved methods of water purification it is imperative that the equipment be of a sufficient size to meet the maximum load that may be put upon it.

Outside of the above three methods none is known to us which will, under all circumstances, produce a water meeting the Government requirements.

PLAGUE-PREVENTION WORK.

CALIFORNIA.

The following report of plague-prevention work in California for the week ended September 16, 1916, was received from Senior Surg. Pierce of the United States Public Health Service, in charge of the work:

FEDERAL AND COUNTY INSPECTION SERVICE.

(For the enforcement of the law of June 7, 1913.)

Counties.	Number inspected.	Number reinspected.	Acres inspected.	Acres reinspected.	Acres treated.		Holes treated.
					Waste balls.	Grain.	
Alameda		103		32,118	10	2,924	150
Contra Costa	5	65	4,320	31,499		11,707	
Stanislaus	84	75	34,360	40,806	920	12,342	
Santa Cruz		35		5,044		3,037	
Merced	32	18	21,063	9,420		6,240	
Monterey [1]	32	16	30,655	8,855		8,885	6,720
San Benito	45	32	36,657	23,481	400	33,010	1,000
Santa Clara [2]	36	2	12,980	700		755	
San Mateo	13		3,938				
Total	247	346	143,973	151,923	1,330	78,900	7,870

[1] Nine hundred acres treated with hose and funnel.
[2] Sixteen miles railroad rights-of-way inspected and treated with grain.

RATS COLLECTED AND EXAMINED FOR PLAGUE.

Cities.	Collected.	Examined.	Infected.
Oakland	20	20	None.
Richmond	24	24	None.
Antioch	64	64	None.
Total	108	108	None.